Analysis of a Dedicated Outdoor Air System and Low Temperature Supply Air Conditioning System

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Abstract: This paper presents the principles and the characteristics of a dedicated outdoor air system (DOAS) and low temperature supply air system. DOAS is offered based on the demands of indoor air quality and the low temperature supply air system is offered based on the demands of saving energy. The two systems are very similar, which is analyzed in this paper. Using actual engineering, we compute the air flow rate, cold load and energy consumption in detail, and provide some good conclusions.

Key words: dedicated outdoor air system (DOAS); low temperature supply air system; indoor air quality; energy consumption

1. INTRODUCTION

After the energy crisis of world was occurred in the 1970s of 20 century, people have realized profoundly the importance of saving energy for the sustaining development of economy. In architecture fields, energy-saving of air conditioning is necessary. The consumption of refrigerating and air conditioning is the biggest among all the architecture consumption whose occupancy is almost 60%~70%. Therefore, many specialists make their efforts researching the air conditioning systems which are energy-saving. The low temperature supply air system is offered based on the demands of saving energy which can achieve: reducing the first cost and the cost of air conditioning units; reducing operating cost; decreasing the height of story for the building; improving the thermal comfort in the room which the relative humidity is smaller; lower fan horsepower and consumption.

Because of the find of SBS, the increasing tuberculosis morbidity and the outbreak of world SRS and bird flu, people pay more attention to the safe of air conditioning system. Dedicated outdoor air system (DOAS) is offered based on the demands of indoor air quality which is the fresh air system and has not return air system. All the supply air is let out through penetration and exhaust. Thus DOAS has unexampled advantages comparison with other air conditioning systems in preventing the diffusion of virus and bacterium.

The low temperature supply air system can save energy and DOAS can increase indoor air quality. It is worth discussing that whether the two systems can be combined so as to offer well-living, comfortable, safe environment. The principle and features of the two systems would be analyzed in this paper. Taking an actual engineering, the air flow rate and cold load and energy consumption was calculated in details, which the supply air temperature is different. Based on the analysis and comparison the results, some good conclusions can be gained.

2. THE ANALYSIS OF DOAS

2.1 The Composition of DOAS

DOAS is a technology which applying the all fresh air system, low temperature supply air technology and heat recovery technology, thus meet the demands that the air conditioning surroundings is healthy, comfortable, safe and energy-saving. DOAS is mostly composed by the following components:

2.1.1 Low-temperature receiver equipment. To ensure the out air temperature of fresh air handling unit is lower than 7℃, the outflow temperature of water chilling unit usually is no more than 4℃. At the present time, the low-temperature receivers have ice storage, double operating mode unit and compression condensing unit. The ice storage system can delivery cold water which is 1~4℃ to the fresh air handling unit. The double operating mode unit operates in the ice making mode and manufacture the lower temperature glycol solution which is be delivery to the fresh air handling unit. Another is the compression condensing unit which the condensing ways have wind cooling, water cooling and evaporation cooling.

2.1.2 Low fresh air handling unit. The out air temperature of fresh air handling unit is no more than 7℃, therefore the special flow fresh air handling unit is used usually.

2.1.3 Indoor sensible cold facility. The sensible cold facilities have fan coil unit, radiation cold roof etc. The low-temperature receiver can make use of the return water of fresh air handling unit whose temperature is about 11℃, of course, it can use the others. Sensible cold facility only deal with the indoor remainder sensible heat load, so the chilled water temperature can be increased, and the evaporation temperature is enhanced, thus the COP is improved.

2.1.4 Heat recovery unit. The heat recovery unit is mounted between the exhaust air system and fresh air system, which can utilize fully the energy of exhaust air so as to decrease the energy consumption. Outdoor air exchange total or sensible heat in the heat recovery unit with indoor exhaust air, then the cooling fresh air is entered fresh air handling unit. It is recognized that the applied unit is total heat recovery wheel which can storage heat and absorb moistness. After the fresh air is humidity handled, it exchanges heat with outdoor air through the heat recovery wheel. In additional the unit can add some other functions, such as filter, sterilization, purification and so on.

2.1.5 Supply air-outlet. The out air temperature of fresh air handling unit is 7℃, so the bigger induction radio or low-temperature special air outlet must be used so as to prevent condensation trouble.

2.2 The Analysis of DOAS

There is not the return air system in DOAS and all the supply air is let out through penetration and exhaust. So the cross pollution of return air coming from many air conditioning rooms can be avoided, thus improve the indoor air quality and reduce the feasibility which the source of infection is diffused. It is the total fresh air supply system, so the fresh air is enough for the air conditioning room especially in which it is the serried personal density. It is energy-saving that the fresh air is preheated by the recovery heat of exhaust air.

The special flow fresh air handling unit is used usually which deal with all indoor latent load and partly or total sensible load. For the personal serried room, the fresh air can remove all indoor loads, so the sensible unit does not used.

If the inlet water temperature in the sensible cold facility is more than the dew temperature ambient, dry operating mode can be worked, no condensation water thus avoiding creating bacterium and mould coming from condensation water. It is benefit for body healthy because of the improving indoor air quality. The chilled water temperature can be increased, for the sensible cold facility only deal with the indoor sensible heat load. The evaporation temperature can be enhanced 6~7℃, thus the COP is improved.

To keep from condensation in the surface of air outlet and guarantee the suitable rate of ventilation indoor, it is necessary to use induction outlet that the induction radio is bigger.

3. THE ANALYSIS OF LOW TEMPERATURE SUPPLY AIR SYSTEM

3.1 The Composition of Low Temperature Supply Air System

In the low temperature supply air system, the cold primary air in air handling unit is sent to the end equipment (air mixed unit or low temperature supply air diffuser), entering into the air conditioning room. The air temperature coming out from air handling unit in the normal air condition system is 10~15℃, and it is 4~10℃ in the low temperature supply air system.

The composition is the same as it of normal system and the only distinguish is the select of cold source and supply air outlet. The cold source can be gained through ice storage system, electrical water chilling unit or direct expansion air handling unit. Temperature of chilled water is various with the supply air temperature. The supply air outlet, whose induction radio is bigger, is the same as it of DOAS.

3.2 The Analysis of Low Temperature Supply Air System

Temperature difference between supply and return air is increased, and supply air rate is decreased. The specification of air handling unit and the duct dimension are lower than in traditional system. The addition, temperature difference between supply and return water is increased and circulating water rate is decreased. Because of the reduction of supply air rate and circulating water rate, the electrical consumption of fan and pump is decreased.

Improving thermal comfort during the lower relative humidity, the relative humidity of room can maintain 55%~60% if the supply air temperature is 13℃, however it can maintain about 40% if the supply air temperature is 4~9℃. Using DOAS, indoor design dry temperature can be increased and energy can be saved when the thermal comfort is same.

Lower supply air rate results in the reduction of ventilation rate which must be considered in the place that the ventilation rate is big.

4. APPLICATION

The air conditioning system of an office of building is analyzed, computing and comparing the supply air rate, cold load and energy consumption during in the different supply air temperature with two systems.

Outdoor dry temperature is 33.5℃, wet-bulb temperature is 27.7℃, atmospheric pressure is 100.5kPa, enthalpy is 88.8kI/kg, and moisture content is 0.02145kg/kg.

Indoor dry temperature is 26℃. The heat load is 27.52W, sensible load is 17.68W, latent load is 9.84W, and humidness load is 0.0041kg/s.The person density of office in China is usually 6~10m^2/p (that is 10~16p/100 m^2). However it is only 2.8m^2/p in this office building. In the air conditioning system the fresh air rate is 30m^3/ (h.p)

4.1 The Calculation Results of Using DOAS

Firstly, the fresh air is delivery to total heat recovery, exchanging heat and humidity with outdoor air. Secondly, it is delivery to fresh air handling unit, being treated and reaching to machine dew point. Lastly it is delivery to the room, eliminating total latent load and part sensible load. The remainder sensible load is treated by indoor sensible facilities, which is fan coil unit in this system.

For the given air conditioning room, the heat and humidness load is known. Thus, when the machine dew point of fresh air handling unit is confirmed which indoor total latent load is removed by it, the moisture content of room is also known, conformed by the following:

$$d_n = d_L + \frac{Q_{nq}}{G_x(2500 - 2.3468t_n)} \qquad (1)$$

Where d_n is the moisture content of room, kg/kg; d_L is the moisture content of machine dew point in fresh air handling unit, kg/kg; Q_{nq} is latent load of room, kW; G_x is fresh air rate, kg/s; t_n is temperature of room, ℃. Utilizing enthalpy entropy chart, other air parameters during the air conditioning process are obtained. Inlet air parameters of fresh air handling unit, which outlet air parameters of heat recovery unit, is computed as follows.

$$h_{w1}=h_w-(h_w-h_n)\eta \qquad (2)$$

$$t_{w1}=t_w-(t_w-t_n)\eta_1 \qquad (3)$$

Where h_{w1} is the outlet air enthalpy of heat recovery unit, h_w is the outdoor air enthalpy, h_n is the indoor air enthalpy; t_{w1} is the outlet air dry-bulb temperature of heat recovery unit, t_w is the outdoor air dry-bulb temperature, t_n is the indoor air dry-bulb temperature; η is the total heat exchange efficiency; η_1 is the sensible heat exchange efficiency.

The handled sensible load by the fresh air handling unit is calculated as follows:

$$Q_{xnx}= G_x\ (h_n-h_L)-Q_{nq} \quad (4)$$

The handled remainder sensible load by fan coil unit is calculated as follows:

$$Q_f = Q_{nx} - Q_{xnx} \quad (5)$$

Where, Q_{nx} is the handled sensible load.

To ensure the dry operating mode of fan coil unit, the initial temperature of chilled water in fan coil unit must be larger than that of dew point of room. The supply air rate of fan coil unit as follows:

Tab. 1 The air rate and load with different supply air temperature in DOAS

Supply air temperature (□)	Supply air rate of FCU (kg/s)	Total supply air rate (kg/s)	Handled sensible load by FAHU (kW)	Handled sensible load by FCU (kW)	Refrigerating capacity of FAHU (kW)	Refrigerating capacity of FCU (kW)	Fresh air load (kW)
4	0.00	0.769	17.68	0.00	40.27	0.00	12.75
5	0.15	0.921	16.90	0.78	39.18	1.62	12.44
6	0.32	1.088	16.14	1.54	38.09	3.23	12.10
7	0.51	1.284	15.37	2.31	36.96	4.92	11.75
8	0.74	1.509	14.59	3.09	35.81	6.65	11.37
9	1.01	1.775	13.81	3.87	34.63	8.43	10.98

Notes: FAHU is fresh air handling unit; FCU is fan coil unit.

Tab. 2 The air rate and loads with different supply air temperature in low temperature supply air system

Supply air temperature (℃)	Indoor sensible heat (kW)	Indoor latent heat (kW)	Fresh air requirement (kg/s)	Total supply air rate (kg/s)	Sensible load of air conditioning unit (kW)	Total load of air conditioning unit (kW)	Fresh air load (kW)
4	17.68	9.84	0.769	0.891	28.12	63.43	32.23
5	17.68	9.84	0.769	0.940	28.19	63.43	31.98
6	17.68	9.84	0.769	0.995	28.27	63.16	31.66
7	17.68	9.84	0.769	1.056	28.37	62.86	31.30
8	17.68	9.84	0.769	1.126	28.49	62.52	30.88
9	17.68	9.84	0.769	1.205	28.64	62.17	30.41

$$G_f = \frac{Q_f}{\Delta h'} \quad (6)$$

Where, $\Delta h'$ is the enthalpy drop of fan coil unit:

Total supply air rate G is,

$$G = G_x + G_f \quad (7)$$

The calculated results with different supply air temperatures are shown in table 1.

Table 1 shows that when the supply air temperature is 4℃, the fresh air handling unit remove indoor total load without sensible facility. However the refrigerating output of it increase which is as less as 15% of 9℃. The higher the supply air temperature is, the more of total supply air rate and the sensible load removed by fan coil unit is. The fresh air load grows small with the increase of supply air temperature.

4.2 The Calculation Results of Using Low Temperature Supply Air System

The fresh air rate of low temperature supply air system is the same as it of DOAS which is mixed with indoor return air, exchanging heat and humidness. Then it is sent to air handling unit, being treated and reaching to dew point, lastly it is sent to the room.

The method of cold air distribution system design[1] is adopted. The detailed calculating results are shown in table 2. The design conditions are the same as in DOAS. Table 2 shows that when using low temperature supply air system, as increment of supply air temperature, the total supply air rate increases, fresh air load and total load of air handling unit reduce.

Comparing table 1 with table 2, When the supply air temperature is less than 5℃, the total supply air rate in DOAS is less than that in low temperature supply air system; however when it is more than 5℃, the total supply air rate in DOAS is more than that in low temperature supply air system.

Because there is not the heat recovery unit in low temperature supply air system, the total load of air conditioning units in the low temperature supply air system is more than about 30% of fresh air handling unit and fan coil unit in DOAS. The fresh air load is more than in DOAS.

A lot of fresh air is required where there are many persons; hence, the fresh air handling unit may be used to treat total load without needing sensible facility.

5. CONCLUSIONS

Based on calculation and analysis of DOAS and low temperature supply system in this paper, conclusions can be obtained as following:

The two systems both can provide comfortable indoor relative humidity when increasing indoor design temperature.

They can save energy, however, the energy consumption of air handling unit of low temperature supply air system is more than that of DOAS because of without heat recovery equipment.

Comparing DOAS with low temperature supply air system, DOAS has no return air system avoiding indoor pollution and improving indoor air quality.

The supply air rate of DOAS is more than that of low temperature supply air system; however, the energy consumption is not more than that of low temperature supply air system.

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